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Interactive Computer Graphics

A

Responsive Planning and Control Tool

for

DOD Program Management



A
DEFENSE SYSTEMS
MANAGEMENT COLLEGE
RESEARCH REPORT

by

Joseph E. Callahan
Commander, U. S. Navy

Carlton F. Roberson
Major, U. S. Army

George H. Perino, Jr.
Major, U. S. Army

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JOSEPH E. CALLAHAN
COMMANDER, US NAVY

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MAJOR, US ARMY

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EXECUTIVE SUMMARY

This report summarizes the methodology, conduct and findings of the Defense Systems Management College (DSMC) research study of Interactive Computer Graphics (ICG) as a tool for program management planning and control. The study was conducted from January 1974 through December 1976. Because of rapid advances in ICG in the early 1970's which ostensibly could lead to the development of ICG managerial applications, DSMC, based upon the interest of Department of Defense (DOD) program managers (PM's), elected to initiate and sponsor a feasibility study of ICG applied to project networking as it might be used in a program management office (PMO). The study was conducted in four phases to meet four objectives: (1) to determine the feasibility of representing and interrogating a program/project network on a graphics console, (2) to determine the feasibility of developing an Interactive Computer Graphics Networking System (ICGNS) software prototype for program management planning and control, (3) to examine the affordability of implementing an ICGNS in the PMO, and (4) to assess the state-of-the-art in industry and DOD regarding existing and/or proposed ICG managerial applications.

The situational aspects of the study involved overall management provided by DSMC; research contributions by DSMC staff, faculty and students; computer facilities and software development by the Computer Aided Design-Engineering/Computer Aided Manufacturing Division (CAD-E/CAM) at the US Army Electronics Command (USAECOM), Fort Monmouth, New Jersey; and "user" assistance by the USAECOM PM's.

Phases I and II of the study resulted in an operating ICGNS software prototype system which provided: (1) graphical display of a program/project PERT network on an ICG cathode ray tube (CRT) console, (2) a tutorial CRT display menu of system functions for simplicity of operator orientation/training, (3) display of specific activity and event description information, (4) display of schedule information, (5) rapid edit (add/delete/change) of a displayed network or windowed portion of a network, (6) recalculation (Re PERT) of edited networks, (7) storage of scratch pad "what if" networks, (8) a limited subnet capability, (9) hard copy output options, and (10) revisions of the Command's primary data base with edited network data.

Phase III addressed ICGNS affordability in the PMO. Four configurations ranging from a single graphics terminal in the PMO (connected to a remote computer mainframe) to a completely self-contained minicomputer ICGNS in the PMO were examined. System costs were categorized as initial hardware costs, initial software costs, and annual recurring costs. The cost figures developed provide for a general comparison by the reader of PMO requirements versus ICGNS configuration, capability, and cost. Although not specifically addressed, generalizations may also be drawn from the costs presented regarding the use of one system by several colocated PMO's.

Phase IV of the DSMC study was a continuous research effort oriented toward assessing the state-of-the-art of ICG managerial applications in both industry and DOD. Through survey and document searches, a number of applications were identified. On the commercial side, representative ICG applications include drafting automation, medical treatment planning, computer aided manufacturing, production control, graphic arts, design engineering, cartography, and some management applications by large corporations such as IBM, Westinghouse, General Electric, Gould, and Phillips. The emphasis in the private sector, however, appears to be on hardware/technology improvements rather than managerial software design.

With respect to DOD, only five ICG systems applicable to program management have been identified by DSMC to date. First there is the ICGNS program management prototype at USAECOM. Two more sophisticated color graphics models, one for planning and one for cost/schedule trend analysis, are available and are being used by the Army PATRIOT PM in Huntsville, Alabama. At USAECOM also, graphics capability has been added to a risk analysis model (VERT). And finally, the Air Force is considering acquiring a graphics capability which has been developed for the Space Shuttle scheduling and resource computer model. In perspective, ICG program management applications in both industry and DOD are still in the embryonic stage.

Based upon the DSMC study findings, recommendations are presented regarding, (1) future DSMC research efforts in the field of program management planning and control, (2) the evaluation of current DOD ICG systems available to the program management community, and (3) the development of DOD requirements for ICG managerial applications to aid in future ICG software design.

CHAPTER I

INTRODUCTION

Background

"In the privacy of his own office, an executive can experiment on a computer display screen with operating graphs that represent business decisions about sales, prices, inventory, and production. The screen is linked to a central computer, programmed so that when an executive indicates changes with a light pen on the screen, the computer revises the curves immediately. The decision maker tests his intuitive judgment by simple analysis of quantitative data and develops a confidence in his decision, knowing that he has rationally considered all alternatives and selected the best one." (1:121)

In recent decades computerized management information systems have greatly increased data availability. However, the use of computer processing has inevitably followed the trend that data expands in proportion to the ability to generate it, rather than the ability to effectively use it. Who has not wished, when faced with reams of printouts, that answers could be generated by an information system as fast as the job of managing generates questions? In essence high-speed computer output has far outstripped the modern manager's ability to analyze all the available data in his day-to-day decision making. Obviously managers must have rapid access to pertinent data which is presented in a concise, comprehensible form if it is to be useful. (2:52; 3:np)

Interactive computer graphics (ICG) is an application of technology that offers an alternative approach for examining, manipulating and communicating data. It provides a new twist to the use of management information systems. Definitely not just a nice-to-have management aid, ICG allows managers to examine, interpret and understand data faster than might otherwise be achievable. Computer graphics is a general term referring to the equipment and programs used for visual output rather than the usual high-speed printer output. A system is said to have interactive computer graphics capability if the operator is capable of commanding the graphic display directly in real-time. (4:86)

Historical Development

One of the first ICG systems was "Sketchpad" developed by Doctor Ivan E. Sutherland in the early 1960's. The purpose of "Sketchpad" was to provide the user with a computer-aided design capability. The gradual evolution of computer graphics technology which has followed this beginning has witnessed various shifts of direction among the proponents of interactive graphics development. Historically, the primary concern in ICG has been oriented

toward development of system capabilities to a point where they could perform any useful, profitable task. Initially this was achieved in the mid-1960's when graphics systems were used in computer aided design-engineering by such companies as General Motors, Lockheed, McDonnell-Douglas, and Boeing. As such systems demonstrated the usefulness of ICG, major interest turned toward ICG system cost reduction. In this respect a widely held view was that time-sharing offered a cheaper approach to ICG systems, and to this end operating systems originally designed for teletypewriter terminals were modified for graphics. Nevertheless, graphics systems were very complex and required considerable programmer expertise for development of application software. Consequently, few time-shared graphics systems achieved success, and those which did were highly specialized user programs run on large, expensive hardware. Typically such areas as graduate research, design automation, simulation, seismology, medical research, process control, and text editing provided a semblance of early ICG experimental and operational systems. (5:50; 6:148; 7:xxvii)

Economic and technical potential of the interactive graphics market became more apparent in the late 1960's as the private sector began to incorporate graphics technology in new computer hardware. Lower hardware costs associated with advanced computer memory technology, spurred greater use of computer graphics which as a rule require substantial processing capability for graphics transformation and manipulation. Now in the 1970's, complete package ICG systems have emerged, and interest in potential management applications for ICG has been intensified. Not to be denied, the management community appears to be on the threshold of large scale ICG integration with existing management information systems. It remains to be seen if ICG management applications of the late 1970's and early 1980's will allow the decision maker to regain the advantage with the "information explosion." (7:xxvii, 8:65)

Research Origin

Because of rapid advances in ICG in the early 1970's which ostensibly could lead to the development of ICG management applications, the Defense Systems Management College* sponsored a symposium on ICG in October 1973. The purpose of the symposium was to discuss the capability of computer generated graphics with representatives of the Department of Defense (DOD) program management community. Symposium attendees consisted of Program Managers (PM's) and PM representatives of all three Services as well as numerous industry participants. (6:181)

The results of the symposium indicated that DOD PM's would use a developed ICG capability if it were applicable to program management planning

*The Defense Systems Management School (DSMS) was redesignated the Defense Systems Management College (DSMC) in July 1976.

and control. Hence, following the symposium, DSMC initiated a study of potential program management planning and control techniques which might benefit from ICG technology.

Obviously in DOD, PM's are charged to deliver their product on time, within budget, and to technical specification. A PM who contracts all or most of the actual work required in a project, must be able to plan, schedule, execute, and control the resources involved in developing and producing the product. The DSMC preliminary study determined that under these conditions, network analysis techniques such as the Program Evaluation Review Technique (PERT) and the Critical Path Method (CPM) could be extremely effective.

Networking, as a general procedure, supports a variety of program management applications such as planning, resource allocation, risk analysis, simulation, and control. Networks can also be represented graphically. On the other hand, networking has traditionally required tremendous administrative resources and few PM's have been able to devote the money and manpower necessary to make PERT, CPM and some other technique responsive to their real time management demands.

In view of these factors, it was advanced by DSMC in late 1973 that interactive computer graphics technology might be used to significantly offset the administrative disadvantages of networking while at the same time increase the response and effectiveness of networking as a planning and control technique to the PM. Consequently, in January 1974, DSMC elected to initiate and sponsor a feasibility study of ICG applied to networking as it might be used in a DOD program management office (PMO).

RESEARCH STUDY OBJECTIVES

User requirements for a responsive program management planning and control tool were the impetus of the DSMC research effort. Inputs from the October 1973 symposium and specific responses from PM's during the DSMC preliminary study, resulted in the list of desired characteristics for an interactive graphics networking system (ICGNS) shown in Figure 1. Based upon these user requirements, four objectives were chosen for the DSMC ICG study:

To determine the feasibility of representing and interrogating a program/project network on a graphics console.

To determine the feasibility of developing a transportable interactive computer graphics networking system (ICGNS) software prototype for program management planning and control.

To examine the affordability of implementing an ICGNS in the program management office (PMO).

To survey industry and DOD regarding existing and/or proposed ICG managerial applications.

ICGNS USER REQUIREMENTS

Graphical display of a project network on a cathode ray tube (CRT).

Display of activity and event descriptions and listings.

Display of cost and schedule information .

Tutorial user interaction with the graphics console to minimize user orientation and training.

Rapid interrogation and edit of displayed networks.

Development and storage of new networks, subnets, edited networks, or scratch pad "what if" networks.

Capability to update the primary program data base with new or revised alternative network data.

Rapid, useful hard copy output of networks and listings.

Minimal cost associated with implementing, operating and maintaining an ICGNS in the program office.

FIGURE 1. ICGNS USER REQUIREMENTS

PURPOSE

Based upon the results of the DSMC research effort, the purpose of this report is threefold. First to summarize the methodology, conduct and findings of the DSMC feasibility study of an Interactive Computer Graphics Networking System (ICGNS) for program management. Second to inform the DOD program management community on the state-of-the-art in the ICG field by summarizing information obtained to date on current ICG efforts in DOD and industry. And third to provide recommendations for future DOD effort in developing ICG managerial applications.

CHAPTER II

METHODOLOGY AND EXECUTION

Organization And Facilities

The situational aspects of the DSMC ICG study involved overall management provided by DSMC; research contributions by DSMC staff, faculty and students; computer facilities and software development by the Computer Aided Design-Engineering/Computer Aided Manufacturing Division (CAD-E/CAM) at the US Army Electronics Command (USAECOM), Fort Monmouth, New Jersey; and "user" evaluation by the USAECOM program managers (PMECOM). Assistance was also provided by the USAECOM Directorate of Management Information Systems (DMIS) which permitted the use of the USAECOM management information system, the Life Cycle Management System (LCMS).

USAECOM participants in the study were selected because of their expressed interest in ICG managerial applications at the 1973 symposium, and because previous CAD-E/CAM Division efforts had provided an active ICG capability (hardware, software, and expertise) at USAECOM. Further, the USAECOM LCMS was a network based planning model, which provided PERT and CPM analysis (Burroughs 5500 batch processing) for USAECOM program managers. The LCMS was developed by USAECOM

"...to provide an integrated management information system that assists the Command in planning, controlling, and monitoring the development and procurement of electronic equipment systems." (9:2)

This system with its large program management oriented data base was thus considered to provide a convenient basis upon which to begin the ICGNS feasibility study.

The hardware available for the study in the CAD-E/CAM laboratory consisted of a Varian 620F/100 minicomputer with 32K (16 bit) words of memory, a card reader, a paper tape punch, a paper tape reader, disk storage, an electrostatic printer/plotter, and an IDIOM* interactive refresh tube with light pen interrupt and alpha/numeric keyboard. Minicomputer software available through CAD-E/CAM included the operating system and utilities, a FORTRAN compiler, and FORTRAN graphics routines. Specific hardware and software nomenclature can be found in reference 10. A diagram of hardware components is presented in Figure 2.

Cost and Schedule

The DSMC study was conducted in four phases corresponding to the four stated objectives. Phase I was designed to demonstrate the feasibility of displaying and interrogating a program network on a CRT. Phase II was a continuation of Phase I and was directed toward developing the prototype software for an ICGNS program management application. Phase III, conducted

*IDIOM: Information Displays Incorporated Model designation.

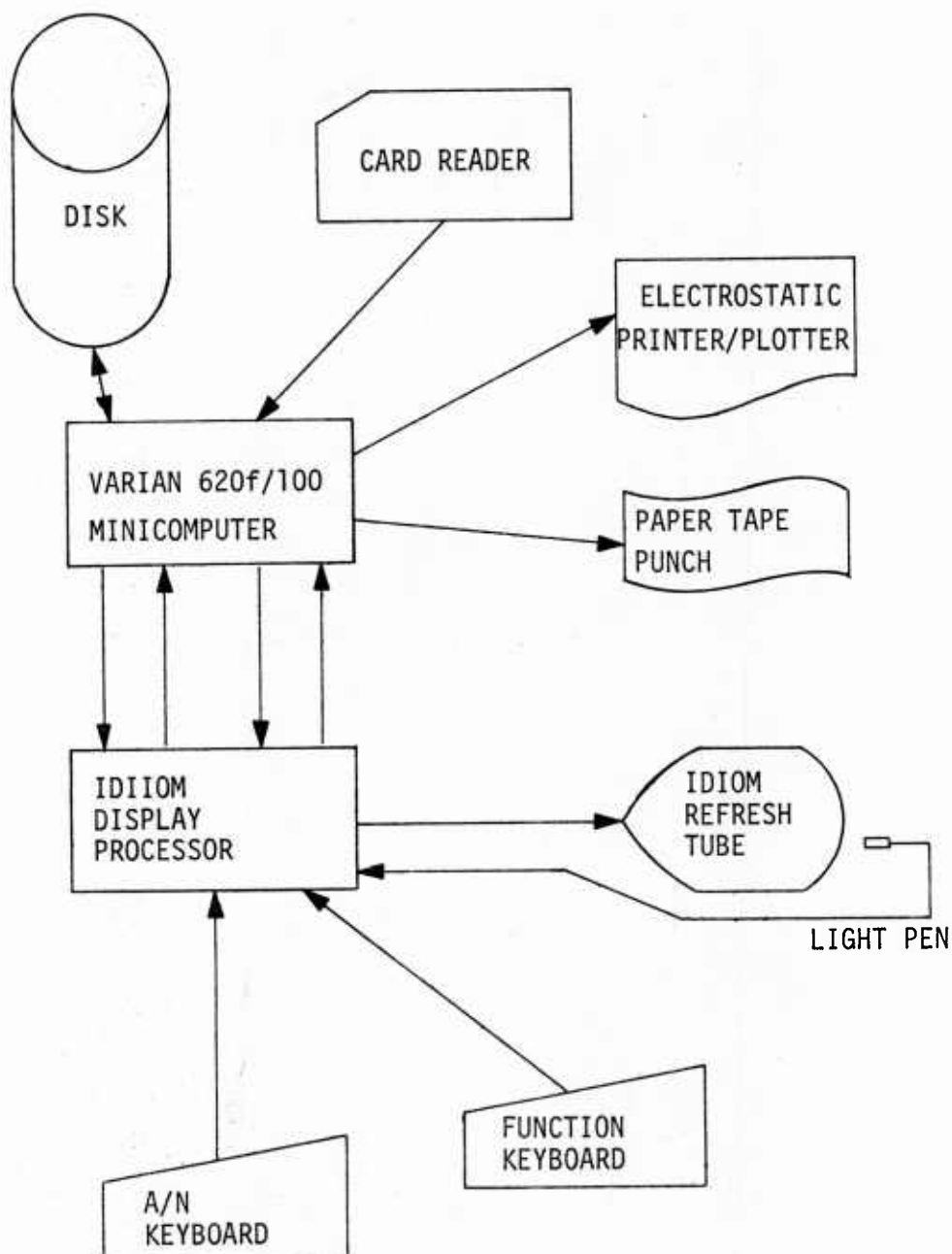


FIGURE 2. ICGNS HARDWARE COMPONENTS

concurrently with the last part of Phase II, was a paper study of the affordability aspects of alternative ICGNS configurations. And finally Phase IV is a continuing survey effort on the part of the DSMC faculty, staff, and selected students to obtain state-of-the-art ICG information from the field.

Funding for the program was incremental corresponding to Phase. Phases I, III, and IV were funded totally by DSMC. Phase II was jointly funded by PMECOM and DSMC.

A summary of both cost and schedule is presented in Figure 3.

Reports

A technical report was written by the USAECOM CAD-E/CAM Division upon completion of each of Phases I, II, and III respectively. These reports are referenced 10, 11, and 12, and are available through the Defense Documentation Center.

Two DSMC student study papers were also published as a result of the DSMC research effort and are available through the Defense Documentation Center and Defense Logistics Studies Information Exchange Service (references 13 and 14).

PHASE I
(NETWORK ON CRT)

PHASE II
(MANAGEMENT APPLICATION)
(PROTOTYPE SOFTWARE)

PHASE III
(AFFORDABILITY)

PHASE IV
(SURVEY/DOCUMENT)
(RESEARCH)

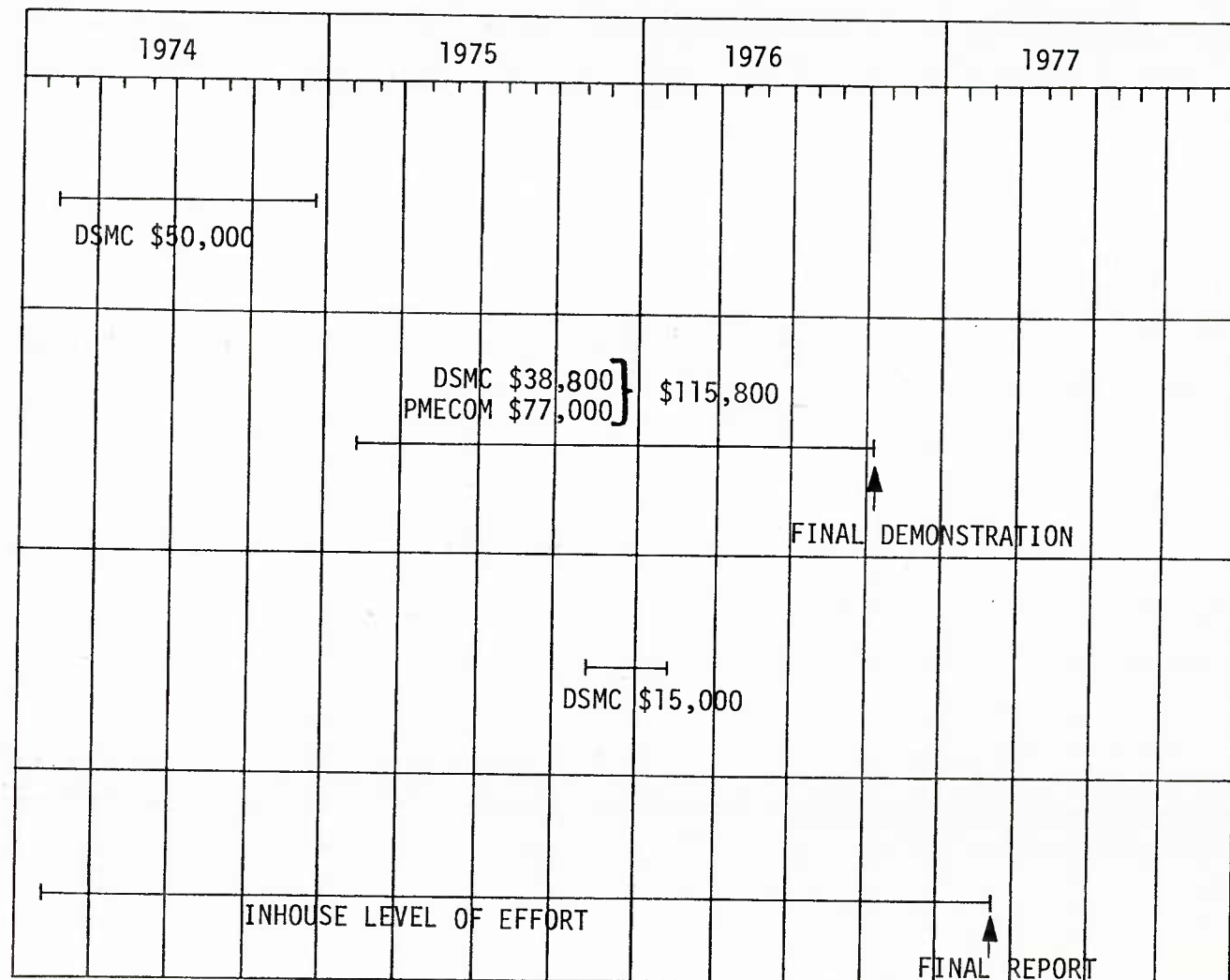


FIGURE 3. ICGNS STUDY COST AND SCHEDULE

CHAPTER III

ICGNS STUDY FINDINGS - PHASE I, II, III

General

The purpose of this chapter is to discuss the results of the ICGNS feasibility study conducted jointly by DSMC and USAECOM. Phases I and II, during which the ICGNS prototype software was developed, are discussed first. Phase III, affordability, follows. Chapter IV presents information collected during Phase IV regarding other ICG development efforts in DOD and industry.

Phases I and II - The ICGNS Prototype

The combined result of Phases I and II was an ICGNS prototype which provided:

- The graphical display of a program/project PERT network in several different formats on a graphics console.

- A tutorial display menu of system functions for simplicity of operator orientation/training.

- Display of activity and event description information.

- Display of schedule information.

- The capability to "window" a specific portion of a displayed network.

- The capability to rapidly edit (add/delete/change) a displayed network or a windowed portion of a network.

- The capability to construct a network at the graphics console itself.

- The capability to recalculate (Re PERT) an edited network.

- Storage of scratch pad "what if" networks.

- A limited capability to subnet.

- Hard copy output of networks.

- The capability to update the LCMS data base with revised network information.

Each of these prototype characteristics will be discussed in view of the original objectives of the ICGNS feasibility study.

ICGNS Input

Initially during Phase I an analysis of the USAECOM LCMS was conducted to identify the data files within LCMS which contained typical program management network information. Since the LCMS provided a batch PERT network calculation for any PM using the LCMS, it was decided for sake of expediency (and economy) that LCMS network data for a project would be converted to graphics through CAD-E/CAM developed, minicomputer software. This compromise early in Phase I, using an initial PERT network calculation by LCMS as ICGNS input, thus imposed the first of several restrictions/limitations on the ICGNS prototype. The prototype was restricted to PERT analysis routines and it was dependent upon the LCMS for initial network calculations. Obviously, future transportability of the ICGNS prototype to another command was at least jeopardized by its dependency on the LCMS. Yet, no restriction was imposed on USAECOM users since any PM using the LCMS would be able to use the developed ICGNS.

Network Displays and Storage

Up to 26 separate project networks can be stored in the current ICGNS prototype. This maximum number was strictly a function of disk storage available in the CAD-E/CAM lab. Each network can be separately identified by user job number, and may be original project networks, subnets, or scratch pad nets. The largest network which can be used on the system is approximately 400 events and 500 activities. This capability approaches the limit of practical use of the graphics console screen itself.

In general the CRT screen format is as shown in Figure 4. A border separates the network display area from margin data display areas. Pertinent project information will always be displayed in the top margin for ready reference. Menu items are displayed in the side margins and enable the user to perform necessary actions on the network itself. A brief description of these functions is provided in subsequent paragraphs. Detailed information regarding these functions is at Reference 10. The menu word functions are activated with the integral graphics console light pen. In the bottom margin, detailed event and activity descriptions may be displayed.

Three network layout options are available (Figures 4, 5, 6). Figure 4 depicts a precedence - centered arrangement where events are located in the X direction according to their time precedence. Equal precedence events in this layout are displayed symmetrically in the Y coordinate direction. The precedence-centered layout makes the most efficient use of the CRT viewing space.

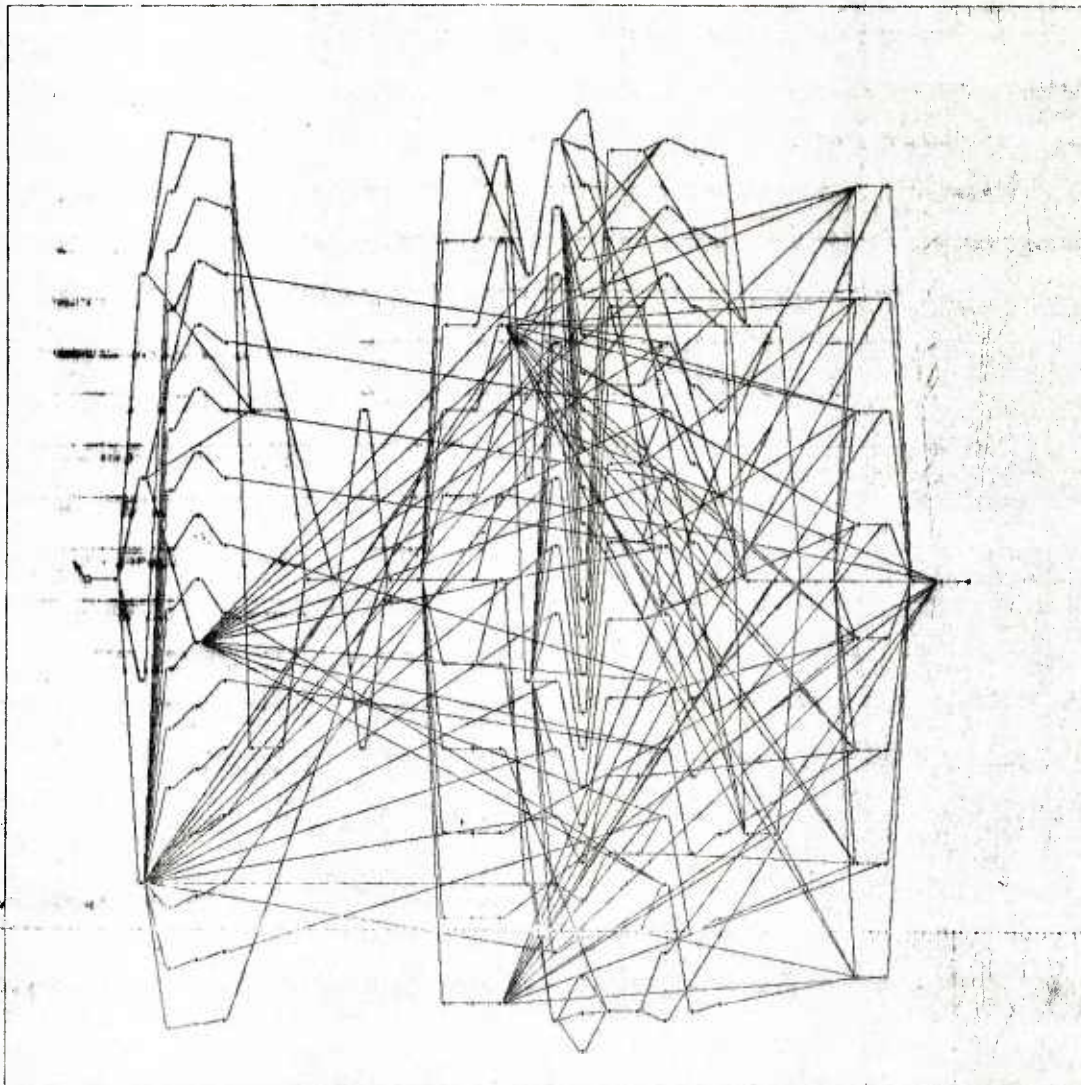
The second layout option, Figure 5, is arranged by event precedence and slack. The critical path is shown as the top horizontal activity-event path and equal precedence events are positioned from top to bottom in the Y direction according to their slack value. Schedule dates for the critical path as well as slack values are also displayed for ready reference. Finally, Figure 6 presents a top-down layout where events are precedence arranged in the X direction and equal precedence events are equally spaced top-down in the Y direction.

USAECOM LIFE CYCLE MANAGEMENT SYSTEM
 SYSTEM 5300000 SUBSYSTEM END DATE 31MAR77
 TYPE NO WASHFAX START DATE 05JUN75 DATA DATE 17JUN78
 NOMENCLATURE WASHFAX FSN
 RESP. MGR. ORG. LEVEL 3 PRIORITY BLUE CHIP

EDIT

FIND IT
 LINES ON
 LINES OFF
 ACTIVITY
 EVENT
 WINDOW

NETWORK
 SUBNET
 PRINT
 PLOT
 LOGEN
 REDRAW



PREDECESSOR	SUCCESSOR	P	DESCRIPTION	L	REP	ACTY	EXPEC	LATEST	PRIMEY	CONTROL	SCHD	SCHD	ACTUAL
ESLN	EVENT	ESLN	EVENT	H			DATE	COMPLETION	DATE	BLACK	DATE	SCHD	COMPLETION
		5300000	1005						0.0	05JUN75	0.0		05JUN75
					1	ACC		05JUN75	05JUN75				05JUN75

FIGURE 4. PRECEDENCE - CENTERED LAY OUT

USAECOM LIFE CYCLE MANAGEMENT SYSTEM
 SYSTEM 5300000 SUBSYSTEM END DATE 31 MAR 77
 TYPE NO WASHFAX START DATE 05 JUN 75 DATA DATE 17 JUN 75
 NOMENCLATURE WASHFAX FSN
 RESP. MGR. ORG. LEVEL 3 PRIORITY BLUE CHIP

EDLT

FIND IF
 LINES ON
 LINES OFF
 ACTIVITY
 EVENT
 WINDOW

NETWORK
 SUBNET
 PRINT
 PLOT
 LOGIN

REDRAW

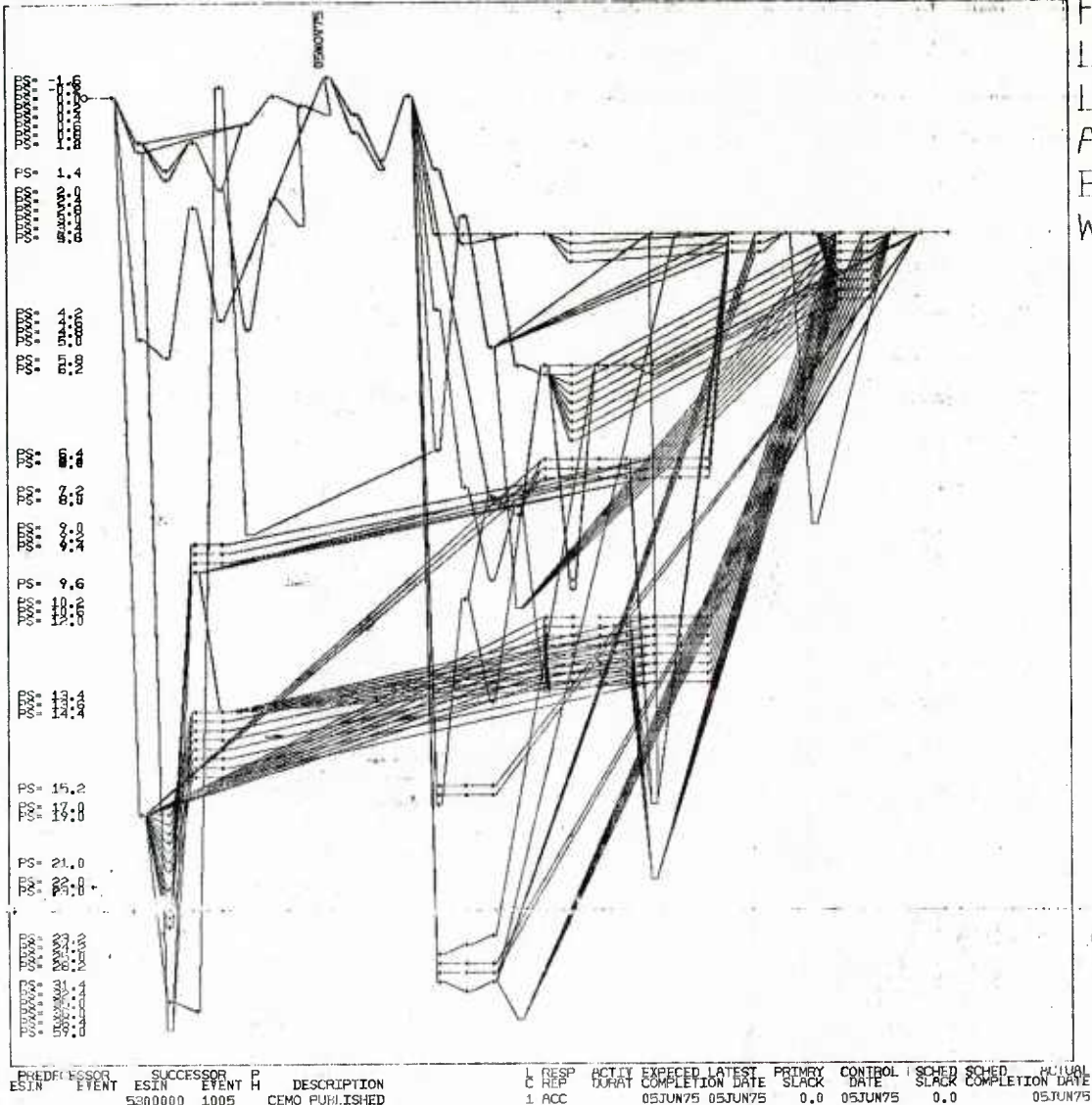


FIGURE 5. PRECEDENCE SLACK LAY OUT

USAECOM LIFE CYCLE MANAGEMENT SYSTEM

SYSTEM 1 SUBSYSTEM END DATE 27JUN75
 TYPE NO TEACUP 2 START DATE 06JAN75 DATA DATE 01FEB74
 NOMENCLATURE 38 AIR DEFENSE ARTY FSN
 RESP.MGR. CAPT. STEIN ORG. CSA LEVEL 3 PRIORITY BLUE CHIP

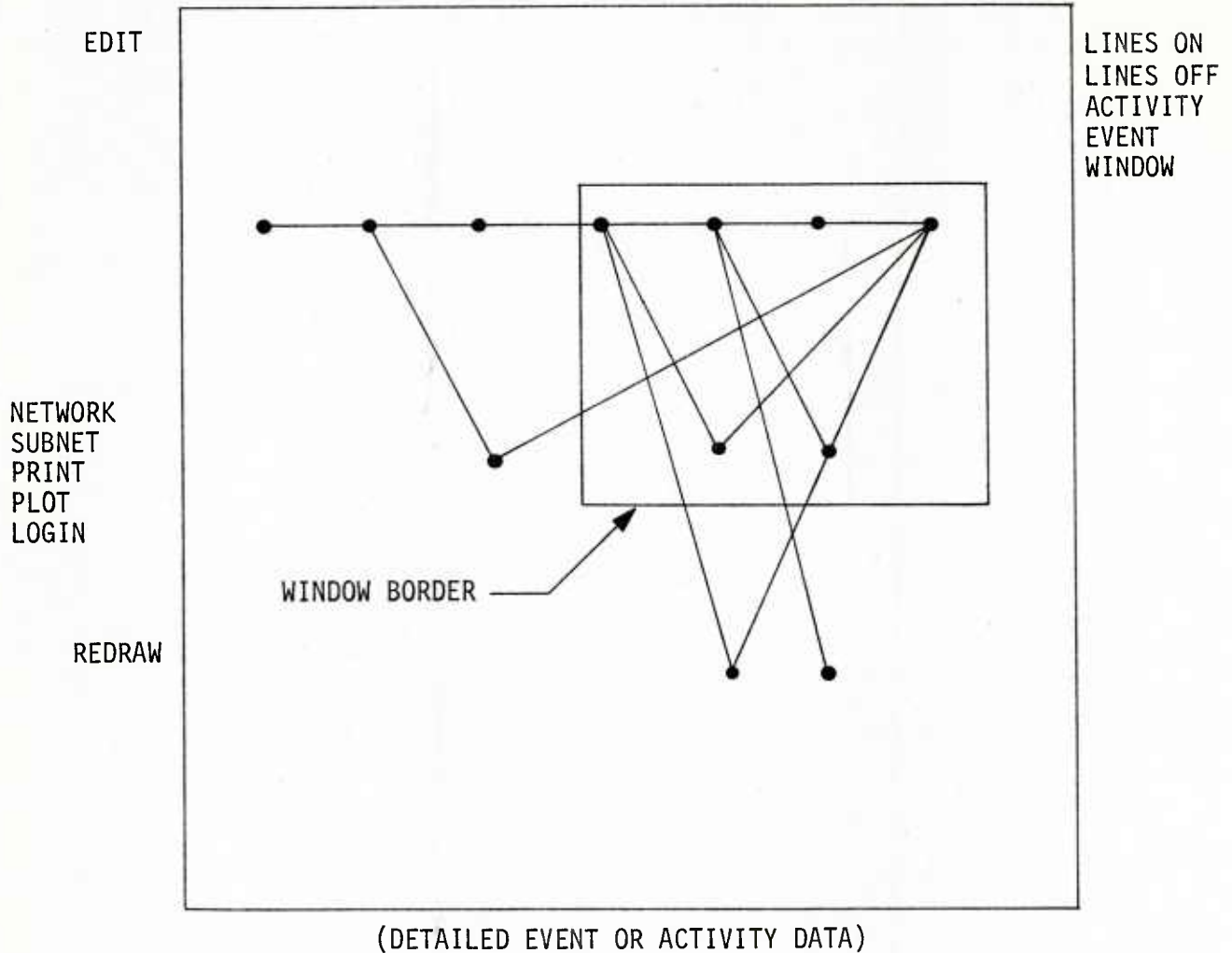


FIGURE 6. PRECEDENCE - TOP DOWN LAY OUT

By selecting the appropriate menu word in the right margin, any of the three network layouts can be displayed with lines-on as shown in Figures 4, 5, and 6, or with lines-off. A detailed or abbreviated event or activity description can also be displayed at any time in the bottom margin by first selecting the appropriate menu word and then touching the desired event/activity with the light pen (see Figure 4). Further, for user benefit, when an event is selected, the event on the CRT screen blinks for immediate recognition. Activity lines are slightly rotated, when they are selected, for ease of recognition.

Window Capability

Because large networks tend to clutter the CRT screen, a windowing capability was programmed. Any portion of a network may be "windowed" (see Figure 6). After selecting the window function from the right margin menu and positioning the window with the light pen over the specific area of the network in question, the windowed portion is enlarged and displayed on the screen (Figure 7). The window display events are shown as numbered boxes, and activity stubs are shown for those activities extending outside the window border. Once the user is finished with the windowed portion of the network, he may recall the basic network and continue his analysis.

Multiple Edit Function

In order to edit existing networks or to conduct scratch pad "what if" exercises with a network, a multiple edit function was programmed. Activities/events can be added/deleted/changed in either the full network or a windowed portion of the basic network. In addition multiple edits can be made. That is, changes can be made in one windowed portion of a network after another. Once all desired changes have been made, a complete PERT calculation is performed. The new (edited) network can then be stored for future use, printed as hard copy, or transmitted to update the primary LCMS data base for the project.

A consideration of interest at this point is the time required for PERT calculations. Depending on the complexity of the edited network, PERT calculation time with the current ICGNS prototype may vary from a few minutes to one-half hour or more. Since calculation time is both prototype hardware and software dependent, this limitation is peculiar to the ICGNS and could be easily overcome by expanding program application. In essence, response requirements of the particular program management office would drive the sophistication (and cost) of network calculation routines.

Subnetting

The ICGNS has a limited subnetting capability, much less than was originally intended. The subnetting capability developed involves only

USAECOM LIFE CYCLE MANAGEMENT SYSTEM

SYSTEM 1 SUBSYSTEM END DATE 27JUN75
 TYPE NO TEACUP 2 START DATE 06JAN75 DATA DATE 01FEB74
 NOMENCLATURE 38 AIR DEFENSE ARTY FSN
 RESP. MGR. CAPT. STEIN ORG. CSA LEVEL 3 PRIORITY BLUE CHIP

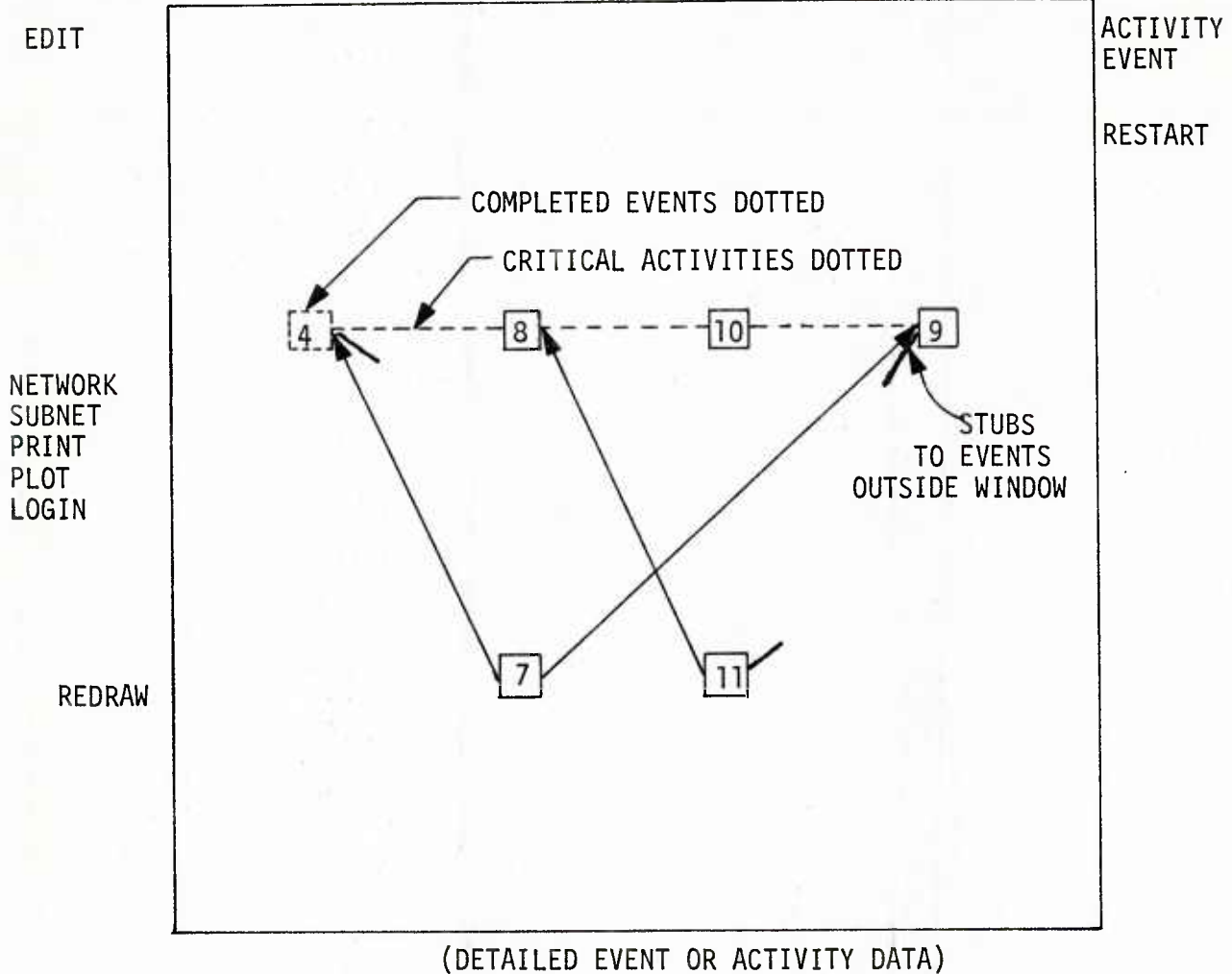


FIGURE 7. WINDOWED VIEW

being able to represent any activity as a separate subnet. For example if "Test Two Prototypes" were an activity in the basic network, this activity could be further defined or drawn as a subnet and stored. Ideally, any edits (changes) of a subnet should be automatically reflected in the basic network. But this is not the case with the ICGNS prototype; editing must be done separately in the subnet and the basic network. Obviously, this limitation of the prototype system requires a more knowledgeable user and increases contact time at the console.

Another limitation deals with types of subnets. If specific functional or hierarchical level coding had been designed into the data base, almost any subnet could be created and displayed. For example, a subnet depicting all report requirements or all test activities and events could be drawn. This capability was not incorporated in the ICGNS data base coding early-on in the study and represents another major limitation of the prototype.

Both subnetting limitations were a result of secondary consideration of the subnet function in early DSMC study planning and a limitation of funds in the latter part of prototype development. Subnetting should be given emphasis in data base design for future ICG development efforts.

ICGNS Output

The ICGNS system as developed produces either a wall size, detailed PERT network chart or a small electrostatic plot of the image as displayed on the CRT. Wall size charts are drawn on a slow, flat bed, paper tape driven plotter used previously by the CAD-E/CAM Division in design work. A recently acquired high speed drum plotter at USAECOM will eliminate this apparent limitation and will enable rapid response for chart requests by USAECOM PM's. On the other hand, electrostatic plots can be obtained at the console in minutes, but they lack the detailed event/activity data available with the wall size chart.

An important feature of the ICGNS is that the output of edited networks can be used to update the primary USAECOM LCMS data base. This inherent flexibility allows any LCMS user the opportunity to use the ICGNS for project planning and control. Multiple PM's who must retain basic program data in their Commands' management information system data base can individually perform "what if" exercises with the ICGNS and then update the LCMS with revised program information.

Transportability

One of the original objectives in the DSMC study was to insure transportability of the ICGNS software. This was not achieved for several reasons, not the least of which was sheer economic limitations. The ICGNS is both hardware and software operating system dependent, and would require major recoding before the existing system could be transferred to another mini-computer graphics configuration. Since Phase III of the study was conducted to examine ICGNS cost, the transportability question was partially answered in terms of developing a final production version of the system. Phase III is subsequently discussed.

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Both subnetting limitations were a result of secondary consideration of the subnet function in early DSMC study planning and a limitation of funds in the latter part of prototype development. Subnetting should be given emphasis in data base design for future ICG development efforts.

ICGNS Output

The ICGNS system as developed produces either a wall size, detailed PERT network chart or a small electrostatic plot of the image as displayed on the CRT. Wall size charts are drawn on a slow, flat bed, paper tape driven plotter used previously by the CAD-E/CAM Division in design work. A recently acquired high speed drum plotter at USAECOM will eliminate this apparent limitation and will enable rapid response for chart requests by USAECOM PM's. On the other hand, electrostatic plots can be obtained at the console in minutes, but they lack the detailed event/activity data available with the wall size chart.

An important feature of the ICGNS is that the output of edited networks can be used to update the primary USAECOM LCMS data base. This inherent flexibility allows any LCMS user the opportunity to use the ICGNS for project planning and control. Multiple PM's who must retain basic program data in their Commands' management information system data base can individually perform "what if" exercises with the ICGNS and then update the LCMS with revised program information.

Transportability

One of the original objectives in the DSMC study was to insure transportability of the ICGNS software. This was not achieved for several reasons, not the least of which was sheer economic limitations. The ICGNS is both hardware and software operating system dependent, and would require major recoding before the existing system could be transferred to another mini-computer graphics configuration. Since Phase III of the study was conducted to examine ICGNS cost, the transportability question was partially answered in terms of developing a final production version of the system. Phase III is subsequently discussed.

Project Network Cost Data

Although the original intent of the ICGNS study was to develop a network planning and control tool which included both cost and schedule data, only the schedule data objective was achieved. The addition of cost algorithms in the prototype would exceed the capabilities of the existing operating system and storage. Cost routines could be developed and run subsequent to PERT calculations, but they cannot be an integral part of the basic ICGNS software without a complete software rewrite. It should be recalled that the DSMC study was aimed at demonstrating feasibility. During the latter part of Phase II, other commercial/DOD advances in the ICG field made further DSMC effort duplicative. Specifically, one color graphics network simulation system had been developed and was being used by the PATRIOT Army program office. Another commercial scheduling and resource allocation graphics system was being marketed to the US Air Force Space and Missile Systems Organization (SAMSO). For these reasons the DSMC ICGNS study effort was terminated prior to adding a cost computation capability to the prototype. However, the prototype is resident and operating at USAECOM and an expansion of the system to include cost data would more than likely be an effective alternative for PMECOM.

Stochastic/Decision Network Computations

The ICGNS was limited to a PERT network analysis. As such, neither simulation nor decision/risk analysis capabilities are available with the prototype. Yet many batch process computer models developed for and within DOD in recent years are of the stochastic simulation type or provide decision/risk analysis capability. The fact that the ICGNS used PERT rather than a more sophisticated stochastic analysis routine is really incidental to the DSMC feasibility demonstration. Given sufficient computer resources, a desired analysis routine could be adapted to graphics. To amplify this point, other models will be discussed in Chapter IV.

Phase III - ICGNS Cost

Phase III of the DSMC study examined the costs associated with ICGNS implementation in a DOD program office. DSMC provided the framework for this paper study and the CAD-E/CAM Division compiled the data and conducted the analysis.

Assumptions

Several baseline assumptions were made for the ICGNS cost study. These were:

An implemented ICGNS would provide for 100 networks, each of 100 events and 200 activities. Network schedule logic and critical path analysis would be provided, but not resource (cost) analysis.

Each network would require update at least once a month.

Central computer requirements would be three hours or less per day (depending on ICGNS hardware configuration and capability).

System response would be approximately 10 seconds once computations were initiated,* but a five minute response for complicated network calculations could be tolerated.

Production of full size network drawings could vary from two hours to forty eight hours (depending on configuration). Small electrostatic print copies would be available immediately.

Costs of ICGNS configurations considered would be categorized as hardware acquisition, software acquisition/conversion, and operating and maintenance (O&S) costs. And all costs would be given in fiscal year 1976 dollars (escalation/discounting ignored).

ICGNS Alternative Configurations

Four ICGNS configurations, as suggested by an article in the Harvard Business Review (15) were considered as alternatives for the cost study. These four configurations, retitled for the study were, Terminal, Drawing, Calculating, and Self-Contained. A summary of the hardware components of each configuration is provided in Figures 8, 9, 10 and 11.

The Terminal setup consists of a graphics terminal in the PMO which is connected to a remote central computer mainframe. All computations, data storage, communications and system management are performed by the mainframe on a time sharing basis. Administrative actions and network edit/update are performed locally in the PMO on the graphics console and then processed by the mainframe at a convenient time. This configuration requires minimal support at minimal cost and is (or should be) an integral part of the Commands' management information system; but, response time on "what if" type exercises is totally dependent on the PM's "priority" at the mainframe.

The Drawing configuration provides the PM with a local minicomputer data storage and graphics conversion capability in addition to the graphics terminal. The PMO can maintain and examine/edit/update its own networks (plans); however, all computations and primary data storage are under the control of the remote central computer mainframe. A printer/plotter is also colocated in the PMO. The Drawing configuration provides essentially the same capability to the PM as the Terminal configuration except that it is somewhat more responsive, being dependent on a mainframe only for computations.

The third configuration, Calculating, provides a semi-stand-alone capability. Network analysis computations can be performed in the PMO. A

*If a remote graphics terminal were used with a central computer mainframe, response time would be network calculation time plus time waiting for access to the main computer.

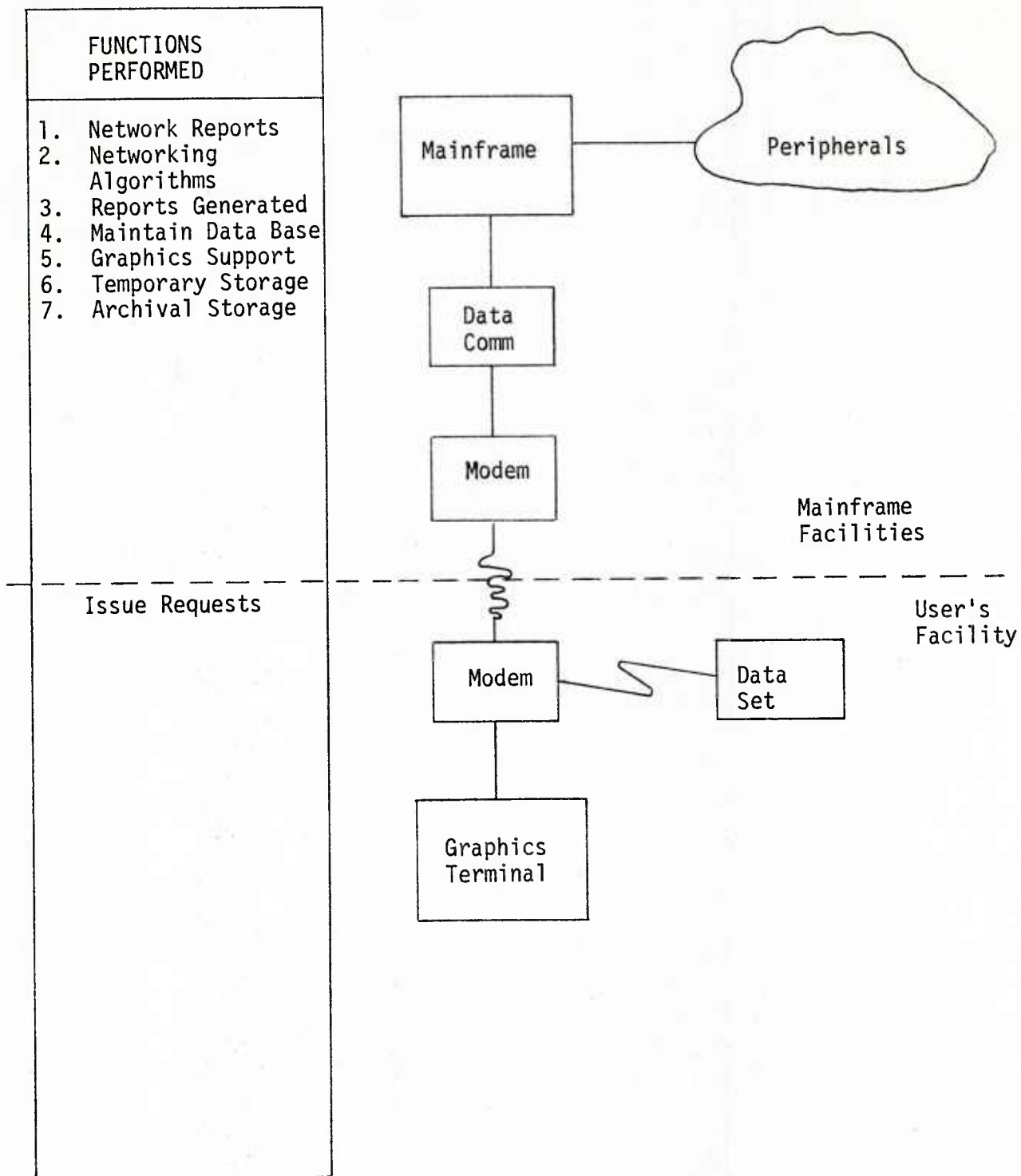


FIGURE 8. GRAPHICAL DESCRIPTION OF TERMINAL CONFIGURATION

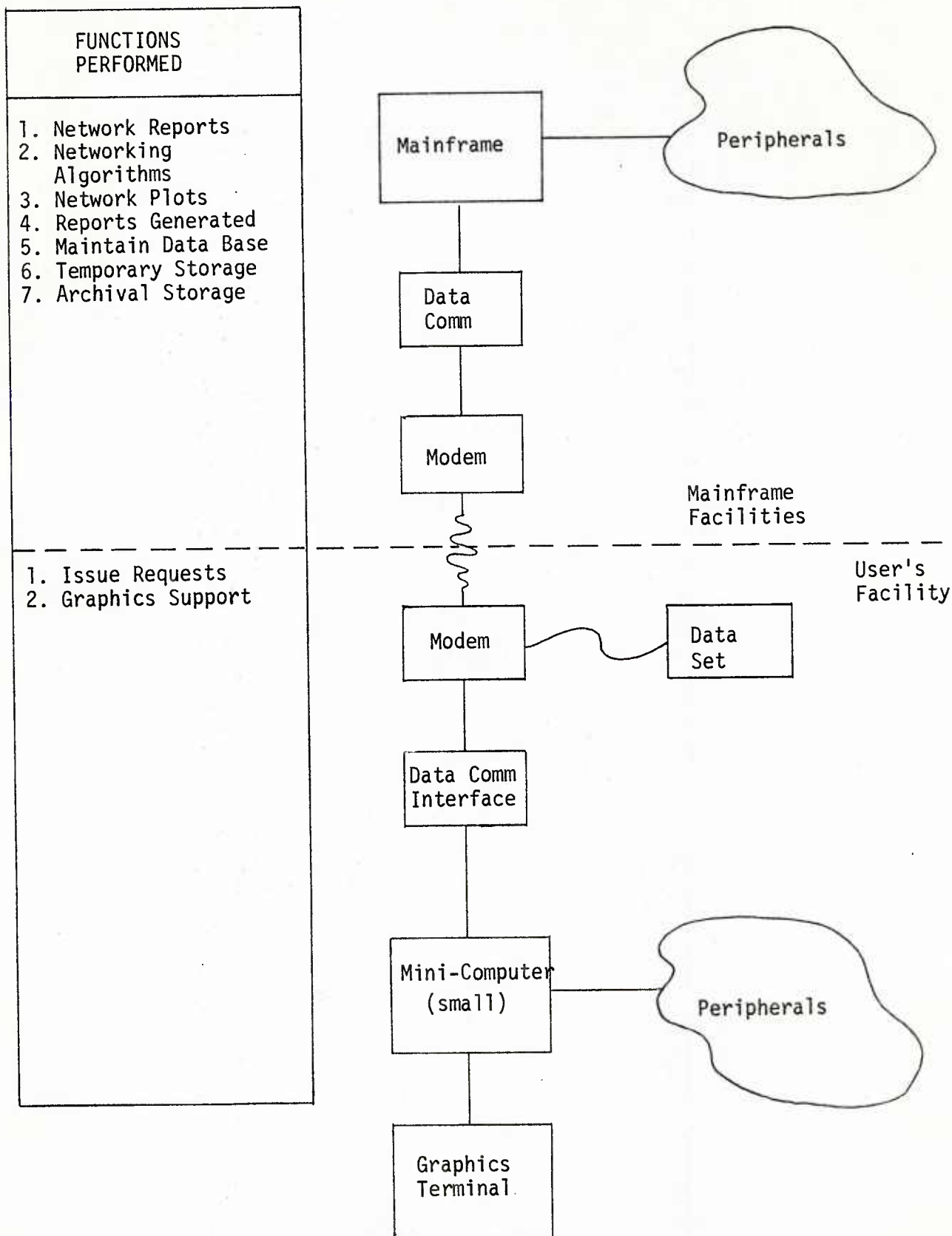


FIGURE 9. GRAPHICAL DESCRIPTION OF DRAWING CONFIGURATION

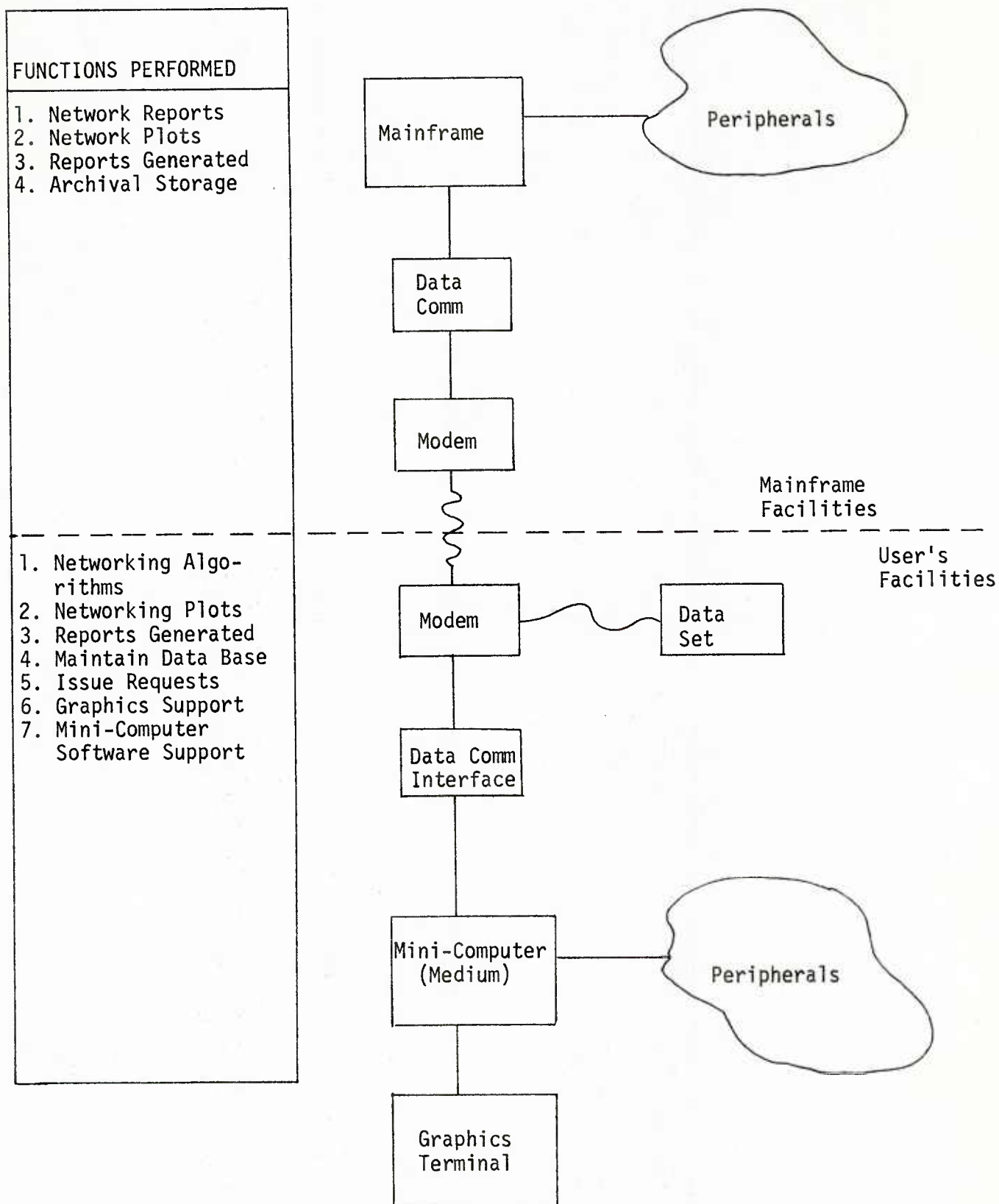


FIGURE 10. GRAPHICAL DESCRIPTION OF CALCULATING CONFIGURATION

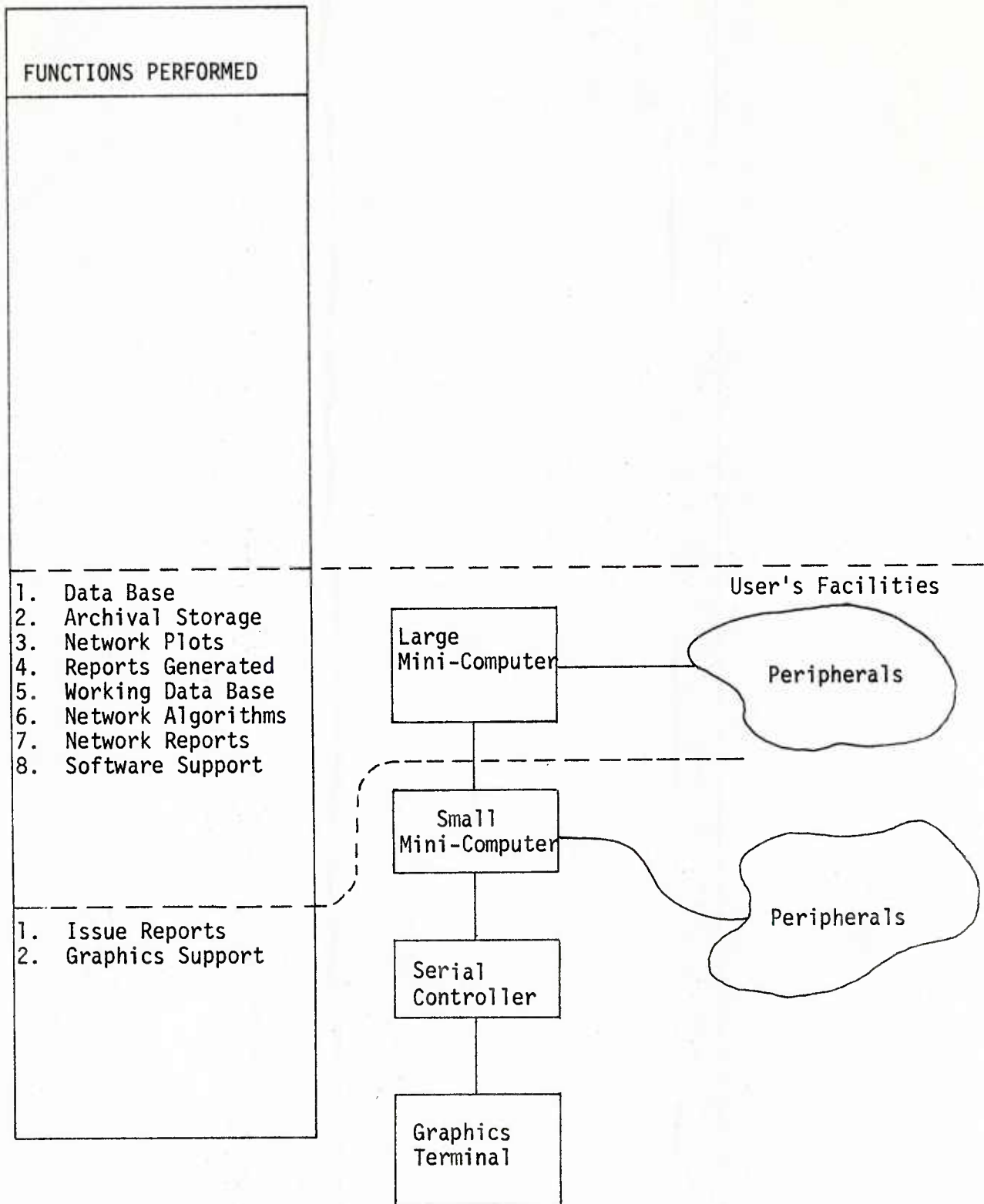


FIGURE 11. GRAPHICAL DESCRIPTION OF SELF-CONTAINED CONFIGURATION

central mainframe is only necessary for massive storage and computations beyond the capability of the PMO minicomputer. This configuration is essentially the same as the current ICGNS prototype. Although it ostensibly could be independent of the Commands management information data base and not require network input such as is the case with the current ICGNS prototype, an interface arrangement between the Command mainframe and the PMO would probably be desired. The Calculation configuration would obviously be very responsive to PMO needs.

Finally, the ultimate in responsiveness is the Self-Contained configuration which provides the PMO a complete stand alone capability.

Configuration Costs

The basic results of the ICGNS cost study are presented for all four configurations in Figures 12, 13, 14 and 15. Figure 12 lists initial hardware cost estimates for a PMO with no ICGNS equipment on hand. Hardware costs are average values typical of similar off-the-shelf commercial items.

Figure 13 presents software cost estimates for initial ICGNS implementation. The implementation application is assumed identical to the ICGNS prototype; that is only network logic and critical path analysis are implemented. Software for implementing resource analysis (cost, manpower, etc.) capability is not included in the estimate. Figure 13 does include a composite estimate for necessary commercial off-the-shelf software (operating system, etc.) in addition to manual conversion of the existing ICGNS software.

The annual O&S cost estimates are shown in Figure 14. These costs include supplies, operating and maintenance personnel, and central computer processing time by particular configuration.

For easy reference, hardware, software, and O&S costs are summarized in Figure 15, and specific details regarding all cost calculations are given in reference 12.

Key Cost Considerations

The cost estimates developed for ICGNS are simplistic by design. First, there are a multitude of variations which could be considered for both ICGNS hardware configurations and managerial applications. Each would have its own unique cost; consequently, the purpose here is to provide ballpark estimates which can be used to appraise the cost impact to potential users. Second, any cost study for a system should take into account the number of users, the number of applications, and the amortization of the system's value over a number of years. Although a cursory analysis of these factors was conducted in the DSMC study, the results of that analysis were too dependent upon the prototype application and cannot be generalized here. Suffice it to say that variants of the costs presented in Figures 12 through 15 can be considered for single or multiple users over a specified life cycle, but additional application costs such as simulation, risk analysis, or resource allocation must be estimated separately.

INITIAL ICGNS HARDWARE COSTS - \$K				
DESCRIPTION	CONFIGURATION			
	Terminal	Drawing	Calculating	Self-Contained
Graphics Terminal	10	10	10	10
Modem	2	2	2	2
Data Set		RENTAL		
Turnkey Minicomputer (small)	-	10	-	10
Data Communications Interface/Serial Controller	0.5	1.5	1.5	1.5
Small Disk	-	-	7	7
Teletype	-	2	2	2
Medium Size Minicomputer	-	-	35	-
Large Disk	-	-	25	35*
Magnetic Tape I/O	-	-	9	16*
Paper Tape I/O	-	-	4.5	4.5
Card Reader	-	-	4.0	4.0
Drum Plotter	-	-	35	35
Line Printer	-	-	5	20
Large Minicomputer	-	-	-	50
Equipment Cabinets	-	1	3	8
Storage	0.1	0.1	0.5	0.5
Total in (\$K)	12.6	26.6	143.5	205.5

*With two drives

FIGURE 12. INITIAL ICGNS HARDWARE COSTS

INITIAL ICGNS SOFTWARE COSTS - \$K				
DESCRIPTION	CONFIGURATION			
	Terminal	Drawing	Calculating	Self-Contained
Operating System (Host) (with file management)*	-	-	-	-
Operating System (Mini)** (with file management)	-	1	5	10
Data Comm	-	included in O.S.	1	2
Software Preparation	-	-	included in O.S.	included in O.S.
Report Generator	-	-	-	-
Plotting Post Processor**	10	10	5	5
Networking Applications	50	50	50	50
LCMS (or equivalent off-the-shelf program)	50	50	50	50
Graphics Terminal Support	15	15	15	15
Total (\$K)	125	126	126	132

*Cost Dependent Upon Site Software Availability

**Off-the-shelf purchase

FIGURE 13. INITIAL ICGNS SOFTWARE COSTS

ICGNS ANNUAL RECURRING COSTS - \$K				
DESCRIPTION	CONFIGURATION			
	Terminal	Drawing	Calculating	Self-Contained
Supplies	0	1	3	5
<u>Maintenance:</u>				
Hardware	1	2	10	15
Software	1	1	1	1
Preventive Maintenance	0	1/2	1	3
<u>Personnel:</u> ⁵				
Operator (GS-06, Series 0332)	20 ¹	- ¹	- ¹	- ¹
Software Engr/Operator (GS-12/13-855)	-	36 ¹	36 ¹	36 ¹
System/Data Base Mgr (GS-12/13-0855)	-	-	46	46
<u>Usage:</u>				
Connect Time	30 ²	25 ³	4 ⁴	-
CPU Time				
Data Storage				
Total (\$K)	52	65.5	101	106

1. This cost includes a burdening factor of 2.0
2. Based upon an estimation of a typical usage level of approximately 2.8 hours connect time per day at \$48 per hour (i.e. \$480/hr CPU at 6 minutes CPU/HR connect time equals \$48/hr)
3. The use of drawing configuration decreases mainframe usage by nearly 20% (compared to terminal configuration)
4. The use of calculating configuration decreases mainframe usage by about 87% (compared to terminal configuration)
5. The GS levels and subsequent series shown indicate a pay level and civil service job series.

FIGURE 14. ICGNS ANNUAL RECURRING COSTS

SUMMARY OF ICGNS COSTS - \$K				
DESCRIPTION	CONFIGURATION			
	Terminal	Drawing	Calcu- lating	Self- Contained
Annual Recurring Costs (Figure 14)	52	65.5	101	106
Initial Software Cost (Figure 13)*	125	126	126	132
Initial Hardware Cost (Figure 12)*	12.6	26.6	143.5	205.5
Grand Total For First Year (\$K)**	189.6	218.1	376.5	443.5

*one-time costs

**1975 Dollars

FIGURE 15. ICGNS SUMMARY COSTS

in view of the primary data base design which will be used in or with the system.

As to PMO affordability, the configuration cost estimates provide for a general comparison with the specific PMO budget slice normally allocated to program planning and control functions. Since O&S (personnel) costs appear as the driving cost element of the ICGNS, some tradeoffs may be available to ease the cost burden. For example, on-board planning and control personnel may assume system operation responsibilities, while local Command maintenance support may be available through overhead. Further, additional ICGNS applications such as simulation, resource allocation, change control, risk analysis, and cost/schedule control systems (C/SCSC) analysis may be adapted for ICGNS use locally by the Command's management information system functional staff.

Finally, a very key cost consideration is the potential of an ICGNS for small PMO's. The inherent flexibility of the ICGNS prototype structured upon the USAECOM LCMS points to the advantage of shared use and expense by multiple small PMO's which are economically forced to depend upon the local Command's management information system resources. A multiple-use arrangement could, in essence, provide the small PMO with a responsive, affordable ICG planning and control tool.

CHAPTER IV

PHASE IV - OTHER ICG DEVELOPMENTS

General

As stated previously, an objective of the DSMC study was to obtain current information about ICG use in both DOD and industry. Largely as a result of DSMC student research, a major part of this Phase IV objective was achieved. Through survey and document searches, a significant number of commercial ICG managerial efforts have been identified; however, by similar efforts only a few DOD applications have been located. Since the survey of DOD has not been completed, this search continues.

During Phase IV as ICG information was obtained, it became apparent that events had overtaken the DSMC feasibility study at USAECOM. For this reason, a convenient termination point for the ICGNS prototype effort was chosen, and Phase III of the DSMC study was ended. Even though active research continues under the DSMC Phase IV objective, for reporting purposes the study has been truncated at the present time. This chapter therefore summarizes Phase IV findings to date.

Commerical Applications

The direction which the business community is currently taking in the use of ICG is exemplified by Gould, Inc., a Chicago-based company, with sales of 1.3 billion. Gould has recently installed a system to aid top-level decision makers which combines a large computer-driven display screen with a computerized management information system. An entire range of information covering inventories to receivables is instantaneously displayed by charts and tables thereby allowing immediate comparisons and analysis of corporate statistics. Individual CRT terminals will eventually be installed in offices of managers both at corporate headquarters and in the field. A manager will then be able to tap codes into a desk top console, and get sales figures, balance sheets, inventories, and the like. Many such categories designated by alpha/numeric codes will be displayed for the whole corporation, for divisions, for product lines, and for other breakdowns. In the near future, significant variances from company operating budgets will be shown automatically by the system to provide a management by exception feature. Ultimately, the capability to ask "what if" questions and to generate probable consequences of various alternatives will be an option available to system users. (8:65)

Computerized management information and decision-making systems, such as the one used by Gould, Inc., include software produced by companies like Tektronics and IBM. The "Plot-10/Decision-Maker", for example, is a business graphics software package marketed by Tektronics since mid-1973. This ICG

system with applications in corporate planning, production scheduling, and investment portfolio management to name a few, took two years to develop and was designed to meet seven objectives:

"Ease of use--not just a conversational, one-step-at-a-time system, but one that actually lets the user know what his choices are.

Availability of different analysis modes, to be combined at will.

Liberal use of graphing for ease of comprehension.

Ease of interfacing with the user's own routines.

A work-file structure to facilitate saving and recalling results.

Extensive report generation capabilities.

Absolutely no programming requirement for the user" (3:np)

Tektronic sources indicate that Plot-10 has met all seven objectives and can be used on computer hardware manufactured by several different companies at nominal rates. (3:np)

"TREND ANALYSIS 370," is an IBM developed management information system software package which among other things is capable of producing color graphs. Working for almost four years with First Chicago Corporation in analyzing executive information requirements, IBM developed the TREND ANALYSIS 370 prototype system which provides rapid, color graphics access to the corporations' large data base. The prototype which as of late 1976 had been tested for a year, is an example of emerging ICG systems which will provide managers the real-time control and manipulation of vital information for decision making. (8:65,66)

Software packages previously made available by IBM include the Information Management System (IMS) used by such companies as Diamond Shamrock of the chemical industry. The Diamond Shamrock system can handle the receipt, credit check, scheduling, authorization for shipment, and routing of an order for shipment in minutes. This system is so responsive that orders received at remote regional sales offices can be completely processed the same day they are received. Such response obviously compliments company cash flow, and justifies the expansion and improvement of Diamond's entire computerized management capability. Since 1972 the company has converted from two large scale computers to one more efficient IBM System 370/Model 158, and has more than doubled visual graphic display units and hard copy terminals to 60 and 100, respectively. Continuing in the same vein, the firm began implementation in 1974 of an on-line financial information system. This system which would automatically involve company upper-level accounting included provisions for interactive CRT display consoles to enable managers to instantaneously examine and compare current financial status data such as expenses, revenues, and profits vis a vis planned budgetary outlays. During this time frame

also, a similar ICG production management system was planned for implementation by Diamond. (16:38)

The expansion of ICG systems by the computer industry to applications other than scientific is exemplified by management information systems used by D.W. Phillips International and Westinghouse Electric Corporation. These systems are an outgrowth of the Information Display, Inc. produced IDDIOM. IDDIOM is a graphics display system which can be used for computer aided drafting and design, computer assisted instruction, simulation, on-line process control, information retrieval, and statistical analysis. (17:np)

A basic goal of D.W. Phillips International in using ICG technology has been to stabilize management overhead which normally climbs with increasing corporate market share and sales. This has been accomplished by Phillips through their more versatile and responsive ICG system which improves management efficiency and speeds internal data communication. Success is attested by the fact that the average number of general management executives per country has not increased in spite of annual growth exceeding 25 percent. (18:47)

Phillips essentially separated the management communications from data processing. The primary emphasis was on interactive data displays which would enable managers to understand the problem at a glance and then work on the problem at the ICG console with a light pen. For example, an executive could instantaneously recall and orient corporate data to various production, inventory or marketing alternatives, and then obtain an immediate prediction on the probable effect of a certain policy decision. A second feature of importance to Phillips was the recording and communicating of the decision process. Video tapes, 35mm slides, and microfiche records of discussions and graphic displays which support each corporate decision can be prepared automatically. These data records of decisions are maintained at Phillips headquarters and can be mailed to affected worldwide branch offices to facilitate more effective company communications. (18:47)

Westinghouse Electric Corporation has implemented an ICG system for middle-management which facilitates judgment and computation in decision making. The basic application involves monthly sales forecasting and production scheduling for major appliances. In the true ICG fashion, data parameters related to the problem are displayed to the manager on the CRT along with a standardized menu format. Data manipulation by light pen and keyboard allows the manager to analyze "what if" alternatives. Because of the standardized CRT menu, the manager does not have to "learn" how to communicate with the computer and the computation and graphic response is rapid so that original "what if" questions are not forgotten. This prototype of future corporate ICG management decision aids has been beneficial to Westinghouse and again points to the potential of ICG management information systems. (18:47)

The previous examples of ICG business applications demonstrate the approach of large companies with their own computer facility. Smaller

companies can also take advantage of current ICG managerial applications through time-sharing service companies.

PLOT***, for example, is an ICG business package used with the General Electric Information Service Business Division's MARK III time sharing network. Simple English commands are used in this system to generate graphic outputs such as line graphs, bar graphs, and scatter diagrams. PLOT*** works with data supplied by the customer and also interfaces with "FAL II" a General Electric (GE) financial analysis language. A primary GE objective in the design of PLOT*** was the reduction of administrative support required for manual graphics preparation. Another desired feature which was achieved was PLOT***'s ease of use by non data processing oriented managers, since an understanding of programming language is not required. (19:224)

To facilitate use by smaller companies, PLOT*** is used together with a worldwide GE management analysis service. This service is provided on a time sharing basis in some 300 locations. Subscription service, one of the options available, provides users with information on GE's analysis of present and future prospects for the United States economy. Another option makes economic, industrial, marketing and financial data banks available to complement the user's own data files. Ostensibly, systems such as PLOT*** provide small companies, through time sharing, a computer graphics and management analysis capability almost equivalent to that of larger corporations. (3:np)

Although PLOT*** does not provide interactive graphics and analysis at the present time, such capabilities are available to small companies. For example, another national time sharing service, which uses IBM System 370 equipment, is the Executive Information Service (EIS) of Boeing Computer Services, Inc. A financial and program management system, EIS is interactive and provides data base information access for depicting status and for estimating changes or forecasting. Financial analysis, budgeting and planning, program management, performance tracking, financial estimating, and "what if" options are included in EIS. It should be noted that EIS graphics were developed for interactive use by managers, not specially trained computer analysts. (20:np)

To summarize briefly, commercial ICG management applications are becoming more numerous and emphasize the direction that the business community is taking toward handling the enormous data explosion which has occurred in the past two decades. Although only a few ICG systems have been reviewed here, they are representative of many others which exist or are being developed today. Before discussing what implications these systems have for the future, a brief survey of DOD ICG systems which have been located is appropriate.

Known DOD Applications

At this point in time, only a handful of DOD ICG program management applications have been identified by DSMC. Although there are many inter-active models which were developed and are being used to some degree in program management, the extension of such programs to graphics appears to have been minimal.

For example, a recent study of computer programs used to support US Army PM's which was conducted by the US Army Management Engineering Training Activity (AMETA) at the request of the US Army Development and Readiness Command (DARCOM) identified 17 interactive computer models which could be or were being used by Army PM's. (21) Of these 17, which incidentally did not include the ICGNS prototype at USAECOM, only three use interactive graphics. Specifically two ICG programs were developed for and are currently being used by the US Army PATRIOT PMO for planning and cost/schedule control, respectively. The third Army ICG application is a locally applied graphics routine used at USAECOM with the Army's primary risk analysis model.

The only other DOD ICG models applicable to program management which have been located by DSMC to date are a schedule/resource model and a risk analysis model used by the US Air Force in the Space Shuttle Program at the Space and Missiles Systems Organization (SAMSO), Los Angeles, California. But even though interactive graphics can be used with these models, the Air Force at this time as not elected to acquire the capability. A brief discussion of each of the DOD models located follows.

US Army PATRIOT PMO

The US Army PATRIOT PM currently uses two ICG systems, a stochastic network planning system which was developed under contract by the Computer Sciences Corporation (CSC), Huntsville, Alabama, and a cost/schedule control (trend analysis) model developed by the Directorate of Management Information Systems (DMIS), US Army Missile Research and Development Command (USAMIRADCOM), Huntsville, Alabama.

First, the planning system, the Automated Tiered Network Simulation Model (AUTONET) is,

"...a network analysis model designed to facilitate rapid evaluation of time and cost interactions and sensitivity for a planned or on-going project. AUTONET is appropriate for use on any effort that can be represented as a network of independent activities. It can be used to analyze the effects on overall project cost and schedule resulting from changes in time, schedule or cost of any activity of the project. Its value lies in the ability of the model in assessing alternatives to baseline plans in an interactive mode." (22:1-2)

AUTONET operates on a mainframe computer complex (CDC 6400 and CDC 7600) through an Anagraph Color Graphics System console. AUTONET offers fixed format menu options and data displays on the CRT to simplify user training/orientation. An edit function allows rapid network alternative analysis

relative to baseline plans. The color feature reduces the requirement for multiple display layouts; that is when the network is displayed on the CRT the critical path is shown in green, and near critical paths are shown in yellow. Hard copy output options (wall chart, electrostatic plot) are also available. (21:1-1)

The model structure is tiered following basically the pattern of a Work Breakdown Structure (WBS). Each activity of a summary network can be represented as a subnet at the next lower level. This breakdown can be repeated to a third level. Basically the AUTONET model treats subnets as computational entities and beginning with the lowest tier "rolls up" successively to the next higher level. A simulation on time and cost is performed which identifies among other things the time critical path, all near critical paths, time and cost distributions, mean completion time, and mean total cost. (21:1-2,1-4)

AUTONET outputs are frequency distributions, summary slack time charts, as well as listings, and these data are presented graphically on the CRT for rapid analyses and report generation. (21:1-5)

The AUTONET does have limitations, the most significant of which is the difficulty of establishing interface activities in the project network. Since each tiered subnet is a computational entity, interface activities cannot be drawn between subnets. Hence, a system of duplicative activities and events must be used in several subnets to properly identify interfaces. On the whole, however, AUTONET is a very effective planning system which provides a responsive ICG planning network analysis capability to the PATRIOT PM.

The second ICG model used by the PATRIOT PMO is a cost/schedule trend analysis model developed by the USAMIRADCOM DMIS. Cost and schedule performance data on magnetic tape are received monthly by the PMO from the PATRIOT contractor. The magnetic tapes are used to automatically update the PATRIOT data base and then an ICG interface program provides cost/schedule trend analysis graphs and listings on the graphics console. Twelve trend charts are generated among which are:

- *Cumulative Budgeted Cost for Work Scheduled (BCWS)
- Budgeted Cost for Work Performed (BCWP)
- Actual Cost for Work Performed (ACWP)

Manpower (planned/actual/forecast)

Management Reserve

Cost/Schedule Variances

Cost Performance Index (CPI)

Schedule Performance Index (SPI)

To Complete Performance Index (TCPI)

Budgeted Cost at Completion (BAC)

on

Estimate at Completion (EAC)

Baseline plot/Contractor Estimate at Completion (EAC)

*For those not familiar with Cost/Schedule Control Systems Criteria (C/SCSC) refer to the Joint Cost/Schedule Control Systems Criteria Joint Implementation Guide (AFSCP/AFLCP 173-15; DARCOM-P 715-5; NAVMAT P5240), 1 Oct 76.

Since all data are based upon the project WBS, the trend analysis data can be studied for specific WBS level 1 and 2 items. Trend analysis plots can be analyzed on the graphics console directly. Specific supporting data can also be displayed on the screen immediately for plot verification. Finally, all graphically displayed data and plots can be obtained in hard copy output for report preparation.

INTERVERT

The primary risk analysis model used in the Army program management community is the Venture Evaluation and Review Technique (VERT) model.

"VERT aids in the identification of risk associated with a program and provides the means to relate all risks associated with the program to provide an overall risk assessment. The technique evaluates program alternatives in terms of risk by means of a network and measures the impact of schedule slippage on time, cost and technical performance of the total program." (21:10)

VERT is available to DOD via the Defense Advanced Research Projects Agency NETWORK (ARPANET). It is not an interactive program; however, recently the Systems Analysis Office at USAECOM developed a graphics preprocessor for VERT under contract with the Network Analysis Corporation, Glen Cove, New York. The addition of graphics enables the VERT network to be displayed on a CRT and edited. VERT output (analyzed network with cost/schedule probability distributions) can also be displayed with an option for hard copy. The use of ICG with VERT has added significant visibility for the analyst into the interplay of network events and according to USAECOM sources has reduced data preparation time by over fifty percent. VERT with graphics is called INTERVERT by USAECOM.

The Transition Model

Another DOD planning and control model which has graphics capability is the Transition Model. This model was developed for the US Air Force Space and Missile Systems Organization (SAMSO) by Martin Marietta, Denver, Colorado. The model is basically concerned with scheduling and costing the transition effort from expendable launch vehicles to the nonexpendable space shuttle. The transition model helps in determining the number of back up expendable launch vehicles which might be required for any particular mission, if the space shuttle cannot be launched. Based upon mission requirements, the availability of resources, and a specific back up policy, the Transition Model provides a feasible (hueristic) schedule of launches and expendable launch vehicle builds. It also provides a supporting cost estimate. (23:1,2)

The output of the model is in the form of schedule and resource requirement diagrams and data listings. With the graphics package, the output can be presented on a graphics console and interrogated or "what if" exercises can be performed concerning alternative schedules. At the present time however, the graphics package, which was developed at the initiative of

Martin Marietta, is not being used by SAMSO primarily because of SAMSO funding limitations. Rather, the model is operated in a batch processing mode and/or through an intelligent teletypewriter terminal. Future efforts at SAMSO may provide for the ICG transition model alternative.

CHAPTER V

IMPLICATIONS FOR THE FUTURE

Research conducted for the purposes of this report indicate that, while the use of interactive computer graphics is fairly well established in such areas as computer aided design, medical research, structural analysis, and text editing, managerial applications are still in an embryonic stage of development. Two reasons for this have become apparent. First, there has been a general reluctance on the part of managers, themselves, to become involved in the design of application software. It is imperative that management take the lead in this effort if the real benefits of interactive graphics technology are to be achieved. The lack of time in the manager's schedule and the failure of previous efforts on the part of the computer experts to meet the needs of real-time decision making work against success in overcoming this stumbling block. Second, the cost of most computer systems has been too high, in the past, to allow for the acquisition of unproven computer capabilities in the budgets of all but the largest organizations. The solution to this problem appears to be more readily at hand than the first with the recent precipitous drop in the cost of computing hardware.

Research also indicates that the computer industry is placing its emphasis on improvements in hardware technology rather than on software design. Marketing brochures collected during the research effort underscore the widespread availability of equipment and disheartening lack of commercially available management application software. This is undoubtedly due to the fact that most of the software for interactive graphics applications has been written by the user rather than the equipment manufacturers and the user has been found largely in the scientific community. Until management becomes convinced that interactive computer graphics capabilities can be a practical and economical aid to decision making and becomes involved in the development of software packages, we will not see rapid and widespread growth in this area.

There are some trends in the computer industry which may eventually increase managerial involvement in developing ICG applications. Two of these are the development of minicomputer based systems and television (TV) compatible graphics. First, future minicomputer interactive graphics systems will be smaller and less expensive. Some of these systems will be "stand alone", but many will be designed to work with a large host mainframe. These time sharing systems should provide ICG access for small companies by allowing responsive local minicomputer processing capabilities such as data base creation, graphic editing and/or interrogation, and alternative plan structuring, while the mainframe performs massive computations and massive data storage. (5:51,52)

The second ICG trend in the computer industry appears to be toward TV compatible graphics. Many factors contribute to this trend. For example,

a television set is a relatively low cost terminal and there are millions of both color and black and white sets currently available. Further research indicates that TV associated memory requirements will be lower in cost and have low power requirements. The potential thus exists of merging computer graphics with picture processing technology which will lead to manipulation of photographic images with computer generated displays. Hopefully the combination of ICG systems with TV compatible graphics at reasonable costs will stimulate entrance of new users in the ICG field and the subsequent development of new, innovative ICG management applications. (5:51,52)

Given the previously discussed developments in system design and utilization of interactive computer graphics capabilities what might we expect to see in the development of planning and control application packages to support DOD major weapons systems acquisition management?

The most obvious and pressing need for development of interactive computer graphics application packages lies in the management information systems employed by program management offices. This need has been recognized as evidenced by programs to support cost/schedule planning and control such as the PATRIOT systems and the USAECOM prototype ICGNS. Other possible application areas abound. A few examples are given below.

Availability of an interactive graphics text editing capability in conjunction with a computerized library of key program management documents would be extremely useful during the early stages in the growth of the program management office when extraordinary demands are placed upon available manpower. Such a system would be an aid in speeding the development of such documents as the systems specification, the program management plan, requests for proposal, source selection plans, contracts, etc. While word processing equipment is currently available from the office machine industry, it is envisioned that an interactive graphics application package would combine the features of on-line text editing with random access to and display of selected segments of pertinent regulations and previously approved key program management documents stored in a centralized DOD computer facility. The user, working at a terminal in the program office, would be able to call up available samples to take advantage of the "corporate memory". The text editing feature would then allow him to integrate his own original work thereby providing a document tailored to his particular requirement.

Another possible application might be in the evaluation and structuring of incentive arrangements for multiple incentive cost plus contracts. An interactive graphics application package would be a natural outgrowth of the work performed by the DOD Program Office for Evaluating and Structuring Multiple Incentive Contracts (POESMIC).^{*} Program management personnel would then be able to generate instant displays of the impact caused by changing such parameters as target cost, target fee, maximum fee, minimum fee, share ratio, and fee pool allocation. Such an application program would be invaluable prior to and during negotiations with the contractor when going-in and counter-offer combinations could be prepared rapidly for analysis and discussion by the government negotiating team. (24:1-5)

^{*}Also referred to as MIAP (Multiple Incentive Analysis Program).

And finally, the program manager must often deal with queries as to the impact of changes in the level of program funding, early or late delivery of subsystems or components, and changes in requirements on his program. Utilizing the capabilities of interactive computer graphics to play "what if" games, he could prepare contingency plans for such potential questions or respond more quickly to "unknown-unknowns." He could, for example, develop a series of curves displaying the probability of certain consequences given one or another set of performance, schedule, and cost objectives. Comparison of these graphic outputs would vividly portray levels of risk inherent in a given set of circumstances.

CHAPTER VI

CONCLUSION - RECOMMENDATIONS

Summary

This report has pointed out several known developments in the ICG field within DOD. As a result of a joint DSMC and USAECOM effort, a prototype ICGNS oriented specifically to program management planning and control requirements is available for PM's at USAECOM. More sophisticated color graphics models, one for planning and one for cost/schedule trend analysis, are available and are being used by the Army PARTRiot PM at USAMIRADCOM. At USAECOM, graphics capability has been added to a sophisticated risk analysis model VERT, and the Air Force is considering graphics for scheduling and resource allocation in the Space Shuttle Program.

On the commercial side, representative ICG applications include drafting automation, medical treatment planning, computer aided manufacturing, production control, graphic arts, design engineering, cartography, and some management applications by large corporations such as IBM, Westinghouse General Electric, Gould, and Phillips. And even in the private sector ICG management applications are still in the embryonic stage with only large corporations pushing the state-of-the-art.

Obviously there are many potential circumstances where ICG could be brought to bear to assist in the management of major weapon system acquisition programs. Major questions include: can such assistance be cost-effective for all DOD PM's vice only major programs with the dollars to acquire and operate such systems? Can one system support several PM's? Should a specific, central service organization or agency be responsible for ICG development or should each DOD PM use his own resources to obtain an ICG capability? What are the DOD ICG management application requirements?

If such pertinent questions are to be answered in view of the apparent potential of ICG to DOD management, it seems that advantage could be taken of lucrative "ICG test beds" which exist at USAECOM, USAMICOM, USAF SAMSO, and possibly other locations. Existing systems could be evaluated in their service peculiar environments for managerial potential and cost ramifications. Additionally, if ICG managerial requirements were coordinated in DOD and made known to industry, private resources might also be channeled toward meeting these requirements in the not too distant future.

In any event, a mission of the DSMC is to provide potential PM's with the latest information regarding policy, procedures, and techniques of DOD program management. To this end, it is essential that data and developments relating to ICG management applications be incorporated in the DSMC curriculum. For until a conclusive appraisal of ICG management potential is completed, DOD PM's must be individually aware of all management tools available to them, assuming again that they individually have the resources to acquire and use such tools.

Recommendations

Based upon the discussion of research conducted by DSMC in the ICG field over the past three years, the following recommendations are presented:

That DSMC continue investigation of advances in program management planning and control regardless of the specific technology (e.g. computer graphics) or planning and control technique (e.g., networking) involved.

That the interactive computer graphics networking technique be advanced as an accepted method of program management planning and control.

That DSMC incorporate all applicable ICG information outlined herein, into the appropriate DSMC courses.

That the Services be encouraged to continue the development of managerial applications of ICG systems and that an evaluation of the existing or in-use DOD ICG systems identified herein, be conducted by potential users at USAECOM, USAMIRADCOM, and USAFSAMSO, and the results promulgated to the DOD weapon systems acquisition community.

That the Assistant Secretary of Defense (Comptroller) (ASD(C)) place added emphasis on monitoring and evaluating ICG progress, developments, and potential applications for program management in consonance with established policies/procedures outlined in DODI 4105.65, "Acquisition of Automatic Data Processing Computer Programs and Related Services," June 1970, and DODD 4105.55, "Selection and Acquisition of Automatic Data Processing Resources," May 1972.

That the ASD(C) coordinate the development of individual Service requirements for ICG managerial applications under guidelines established in DODI 4105.65 and DODD 4105.55, and that such requirements be coordinated throughout DOD and made known to the private sector so that future industry and government efforts are oriented toward established DOD ICG managerial needs.

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